PART VII

TECHNICAL SYSTEM DESCRIPTION AND QUALIFICATIONS

A. SYSTEM DESCRIPTION AND PERFORMANCE

1. Communications Paths

The following describes the communication paths between the three (3) basic system components:

- User terminals,
- Spacecraft payload,
- Ground station.

Transmission from the user terminals to the ground station through the spacecraft payload segment is called the "INBOUND link".

Transmission from the ground station to the user terminals is called the "OUTBOUND link".

The communication path starts with the OUTBOUND interrogation transmissions. These OUTBOUND transmissions provide time synchronization and query of each addressed user terminal to see if it requires a position determination or data.

The addressed user terminal, in synchronization with the OUTBOUND received channel and a pre-determined acknowledgement protocol, responds through an INBOUND channel to the ground station.

The world coverage of the system allows the choice of two (2) possibilities :

- Several regional determination/communication systems (CONUS, South America, Europe...),

- World-wide coverage determination/communication system.

Differences between the two options are in the capability of the space segment.

The regional determination/communication system is a non-regenerative payload using repeaters on the VHF 137 MHz and 148 MHz links.

The system described hereafter is the regional coverage system. The INBOUND and OUTBOUND links are the same in the two options.

2. System Description

At VHF frequencies, there are a number of users who could interfere with the STARNET system. Presently, Applicant proposes two quite similar solutions differing by the type of modulation.

In order to limit interference between STARNET and existing systems, STARNET will nominally use pseudo-noise (PN) spread spectrum techniques to spread the energy of the communication channels :

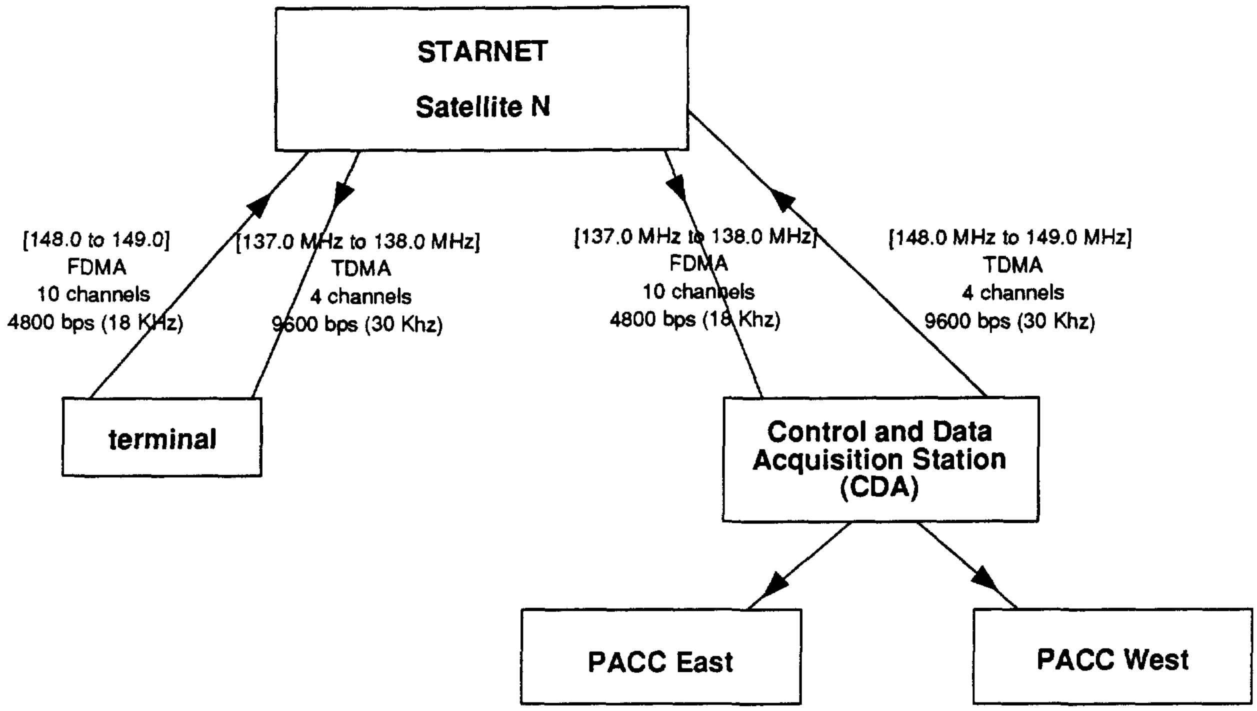
- in 1 MHz for the uplink channels (148 - 149 MHz),
- in 1 MHz for the downlink channels (137 - 138 MHz).

Note: The two following solutions have similar link budget and capacity. Link budget and capacity have been calculated for solution B.

2.1 Solution A

OUTBOUND and INBOUND links are spread to 1 MHz using the uplink (148 - 149 MHz) and downlink (137 - 138 MHz) VHF. Solution A organization with 10 INBOUND channels and 4 OUTBOUND channels also used in solution B.

Applicant is requesting for solution A authorization to operate on a modified primary basis in the US on the VHF bands between 148.0 and 149.0 MHz (uplink) and 137.0 and 138.0 MHz (downlink).



General Diagram
INBOUND OUTBOUND Links Solution A

Figure VII.A.2.1

2.1.1 Channel Bandwidth Requirements:

Inbound channels:

• Bit rate	:	4 800 bps
• Communication bandwidth	:	14 400 Hz
• Frequency error	:	3 000 Hz
		17 400 Hz

Channel bandwidth	:	18 kHz

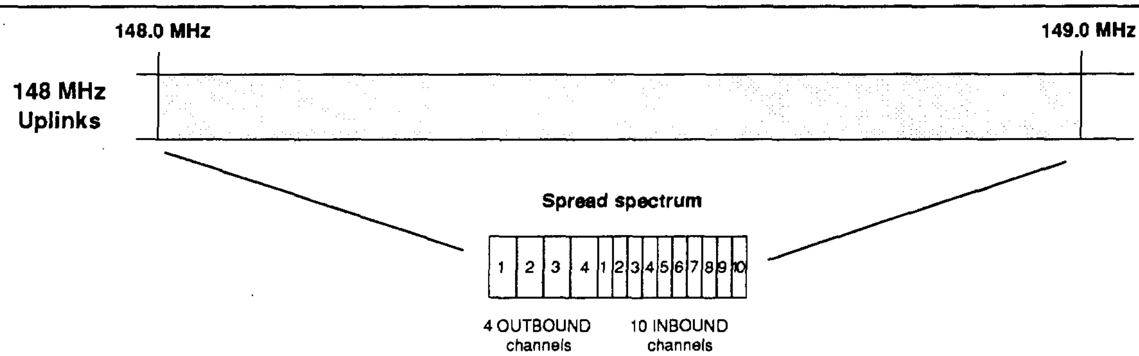
Outbound channels:

• Bit rate	:	9 600 bps
• Communication bandwidth	:	28 800 Hz
• Frequency error	:	300 Hz
		29 100 Hz

Channel bandwidth	:	30 kHz

2.1.2 Uplink

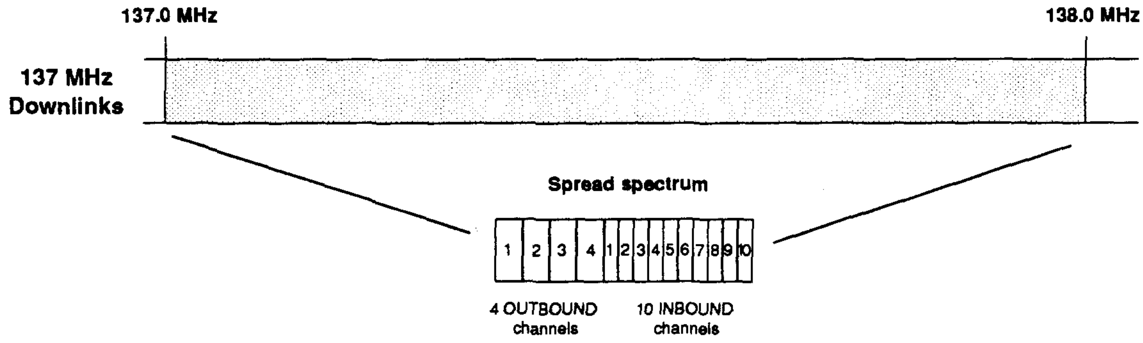
The spectrum assignment for the (148.0 - 149 MHz) uplink is shown below.



Base line STARNET spectrum proposal (solution A)

2.1.3 Downlink

The spectrum assignment for the (137 - 138 MHz) downlink is shown below :



Base line STARNET spectrum proposal (solution A)

2.2 Solution B (see Figure VII.A.2.2)

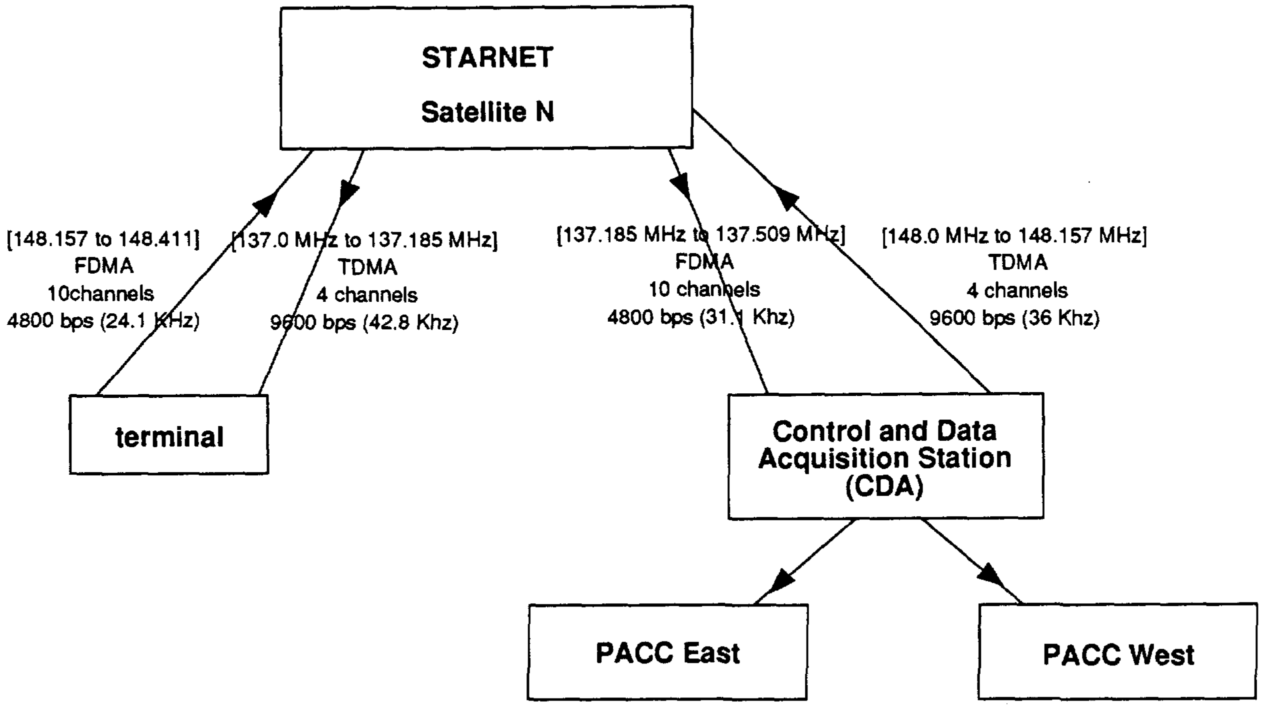
2.2.1 Outbound Link

Data in the OUTBOUND link, FFSK modulated, is structured in frames. Each frame is time logged, has a frame number, contains data and serves as a time epoch t_0 for response from the user's terminals.

Applicant is requesting authorization to operate on a modified primary basis in the US on the VHF bands between 148.0 and 148.385 MHz (uplink), and between 137.0 and 137.509 MHz (downlink). In order to increase the capacity of the system and to comply with the CCIR recommendations, the **OUTBOUND link will use four (4) different TDMA OUTBOUND channels** (9600 bps each).

Frequency bands used for the four OUTBOUND channels are :

- 148.0 -> 148.157 MHz (uplink between ground station and satellite),
- 137.0 -> 137.185 MHz (downlink between satellite and user's terminals).



General Diagram
INBOUND OUTBOUND Links Solution B

Figure VII.A.2.2

2.2.1.1 Outbound channels bandwidth requirements:

Outbound uplink channels characteristics (ground station -> satellite)

Total bandwidth used by the 4 channels:

- 148.0 MHz -> 148.157 MHz
  (13 KHz guard band)

• Bit rate	:	9600 bps
• Communication bandwidth	:	28 800 Hz
• Doppler shift	:	6 700 Hz
• Frequency error	:	300 Hz
		35 800 Hz

Outbound downlink channels characteristics (satellite -> user terminals)

Total bandwidth used by the 4 channels:

- 137.0 MHz -> 137.185 MHz
  (with 13.8 KHz guard band)

• Bit rate	:	9600 bps
• Communication bandwidth	:	28 800 Hz
• Doppler shift	:	13 000 Hz
• Frequency error	:	1 000 Hz
		42 800 Hz

2.2.1.2 Outbound link budgets (see Figure VII A.2.2.1)

Outbound uplink channels analysis (ground station -> satellite) :

- Ground station transmitting/channel : 12 dBW
- Ground station transmitter losses : -0.7 dB

- G/T : +16 dBi
- Max range (3500 km) : -146.6 dB
- G/T at 5° elevation angle : +5 dBi
- Satellite receiver loss : -2.5 dB
- Polarization loss : -3 dB
- To receiver : -201 dBW/Hz
- 9600 bps : 39.82 dBHz
- C/No : 80.20 dBHz
- Eb/No : +4.5 dB
- Uplink margin : > 30 dB

Outbound downlink channels analysis (satellite -> users terminals):

- Satellite transmitting/channel : 9 dBW (7.95 watts)
- Satellite transmitter loss : -0.7 dB
- G/T at 60° off-axis : +4 dBi
- Max range (3500 km) : -145.93 dB
- G/T at 5° elev. angle : +2.5 dB
- Terminal receiver loss : -2.5 dB
- Polarization loss : -3 dB
- To receiver : -200 dBW/Hz
- 9600 bps : 39.83 dBHz
- Eb/No with coding : +2.5 dB
- Downlink margin : +3 dB
- Power flux density at the ground : -141.50 dBW/m^2/4 kHz (dBW/m^2/4 kHz) (1300 km)

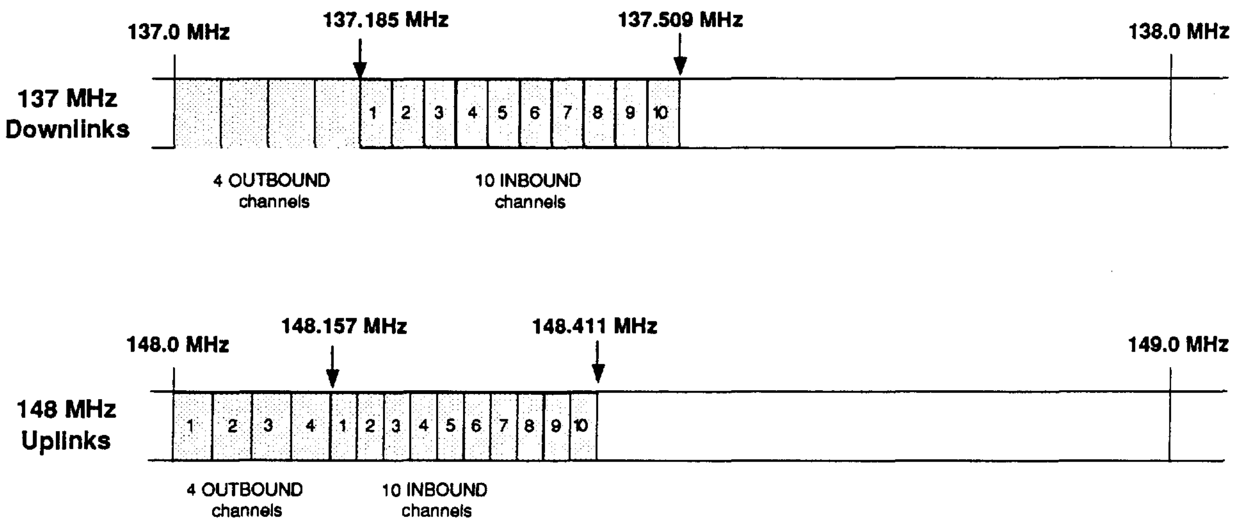
2.2.2 Inbound Link

User terminal data in the INBOUND link modulated FFSK is transmitted by short bursts (100 characters maximum) in synchronization with the received OUTBOUND link. Each response employs a frame structure including a synchronization preamble, an acquisition segment and data.

INBOUND link will be done on 10 different FDMA INBOUND channels (4800 bps each).

Frequency bands used for the ten INBOUND channels are :

- 148.157 MHz -> 148.411 MHz (uplink between terminals and satellite),
- 137.185 MHz -> 137.509 MHz (downlink between satellite and ground station).



Base line STARCOM spectrum proposal (solution B)

2.2.2.1 Inbound channels bandwidth requirements:

Inbound uplink channels characteristics (user's terminal -> satellite)
Total bandwidth used by the 10 channels:

- 148.157 MHz -> 148.411 MHz
  (with 13 KHz guard band)

- Bit rate : 4800 bps
- Communication bandwidth : 14 400 Hz
- Doppler shift : 6 700 Hz
- Frequency error : 3 000 Hz

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24 100 Hz

Inbound downlink channels characteristics (satellite -> ground station)
Total bandwidth used by the 10 channels :

- 137.185 MHz -> 137.509 MHz
  (with 13 KHz guard band)
- Bit rate : 4800 bps
- Communication bandwidth : 14 400 Hz
- Doppler shift : 13 000 Hz
- Frequency error : 3 700 Hz

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31 100 Hz

2.2.2.2 Inbound link budget:

Inbound uplink channels analysis (terminal -> satellite) :

- 148.157 MHz -> 148.411 MHz
- Ground terminal : 0 dBW(1.0 watt)
- Terminal transmission loss : -0.7 dB
- G/T at 5° elevation angle : +3 dBi
- Max range (3500 km) : -146.6 dB
- Satellite G/T at 60° off-axis : +4 dBi
- Receiver loss : -2.5 dB
- Multipath propagation effect : -3 dB
- Polarization loss : -3 dB
- To satellite : -201 dBW/Hz
- 4800 bps : 36.82 dBHz
- Eb/No (10^{-5}) with coding : +4.5 dB
- Uplink margin : +9.9 dB

Inbound downlink channels analysis (satellite -> ground station) :

• 137.185 -> 137.509 MHz		
• Satellite transmitter/channel	:	-3 dBW
• Satellite transmission losses	:	-0.7 dB
• G/T at 60° off-axis	:	+4 dBi
• Max range (3500 km)	:	-145.93 dB
• G/T	:	+16 dBi
• Ground station receiver loss	:	-2.5 dB
• Polarization loss	:	-3 dB
• To receiver	:	-200 dBW/Hz
• 4800 bps	:	36.83 dBHz
• Eb/No (10^{-5})	:	+4.5 dB
• Downlink margin	:	+5.5 dB
• Power flux density at the ground (dBW/m²/4 kHz)(1300 km)	:	-153.5 dBW/m²/4 kHz in any 4 kHz band

2.3 Capacity

Outbound link capacity:

Sufficient margin exists to support an 38 400 bits/s OUTBOUND link with one satellite. If we assume an efficiency factor of 0.7 to account for framing set-up, repetitions and queueing (0.9 framing efficiency, 0.74 repetition / queue efficiency) and a mean message of 32 characters, **we obtain an expected capacity for each satellite of 375 000 OUTBOUND messages per hour.**

Assuming that all the traffic is in continental areas, the following capacities can be expected:

- **a world-coverage capacity of about 3.10^6 messages/hour for the system (70 million users per day),**
- **a CONUS coverage capacity of greater than 350 000 OUTBOUND messages per hour or 8 million users per day;**

Inbound link capacity:

The INBOUND link capacity is driven by the number of simultaneous messages that can be received, and the average message length. In each INBOUND channel, messages are separated by Doppler shift.

The number of simultaneous messages N per second may be derived from the following formula :

$$N = - K (W/b) \cdot (1/M) \cdot \text{Log } P_{NC}$$

Where :
K = INBOUND channels (10),
W = bandwidth of each channel (25 000 Hz),
b = communication bandwidth of each channel (14 400 Hz),
M = message length (expected 60 ms at 4800 bps),
PNC = non-collision probability (PNC 0.6).

The number of simultaneous messages during M = 60 ms on the INBOUND link is thus N = 147. The INBOUND capacity per satellite is about 530 000 messages per hour, or more than 12 million users per day.

The above capacity is significantly increased when the spread spectrum technique is used. In that case, the inbound link capacity is driven by the number of simultaneous messages N that can be received assuming that we have sufficient supply of acquisition units and decoders to handle the link capacity.

The number of simultaneous messages depends on the inbound uplink margin and on the spreading gain (10 dB).

Eb/N0 margin	Simultaneous messages number	Average messages per second	Average messages per hour
3 dB	26	286	1.03×10^6
6 dB	40	440	1.59×10^6
9 dB	46	506	1.82×10^6

3. Space Payload

Use of satellites in non-geostationary orbits is motivated by the possibility of gaining the following system advantages :

- Low EIRP with 60° "field of visibility" antennas,
- Use of simpler spacecraft and launch vehicles.

3.1 General

A VHF (148 - 148.411 MHz) STARNET repeater receives the radiated signals from the ground stations and the user's terminal uplinks and retransmits the signals to the ground station and the user's terminal on the VHF downlinks (137 -> 137.509 MHz).

The ranging and the Doppler shift of the INBOUND link signal together with the knowledge of the satellite position and the OUTBOUND time epoch allow to determine the terminal position.

VHF 137 and 148 MHz spacecraft input

Spacecraft interface:

Parameter	Value	Comments
Receiver noise temperature	600°K	maximum over life of S/C
Input signals		
Maximum terminal input signal power flux density	-120 dBW/m2	assuming1300 km orbit
Nominal terminal input signal power flux density	-142 dBW/m2	assuming1300 km orbit
(random orientation of user terminal antenna with respect to spacecraft nadir)		
<u>Unwanted signals</u>		
Integrated effective background noise :		
. Expected maximum	10 000°K	industrial areas
. Expected nominal	6 000°K	
. Expected minimum	2 500°K	
. Voice signals		intermittent (short 25 watts emissions)

VHF 137 MHz spacecraft output

In the case of spread spectrum (solution A), the power output of the transmitter is 15.6 dBW in a 1 MHz band.

3.2 Satellite block diagram

Figure VII.A.3.2 shows the overall architecture of the LEO satellite. As can be seen, the two VHF potential sources (148 MHz) can be routed via the cross point switch to either of two possible outputs.

4. Orbital Network, Coverage Network

The satellite constellation is designed to give global coverage with minimum waiting time over the CONUS. The orbit altitude is constrained to assure adequate power from the solar-cell arrays over a seven-year lifetime. The consideration here is to select the orbit not only from coverage considerations, but also to satisfy a constraint on a tolerable flux of high-energy protons.

About twenty-four (24) satellites are distributed randomly on 50° to 60° inclined planes in circular orbits at 1300 km. The randomly distributed constellation does not necessitate a complex tracking and management scheme.

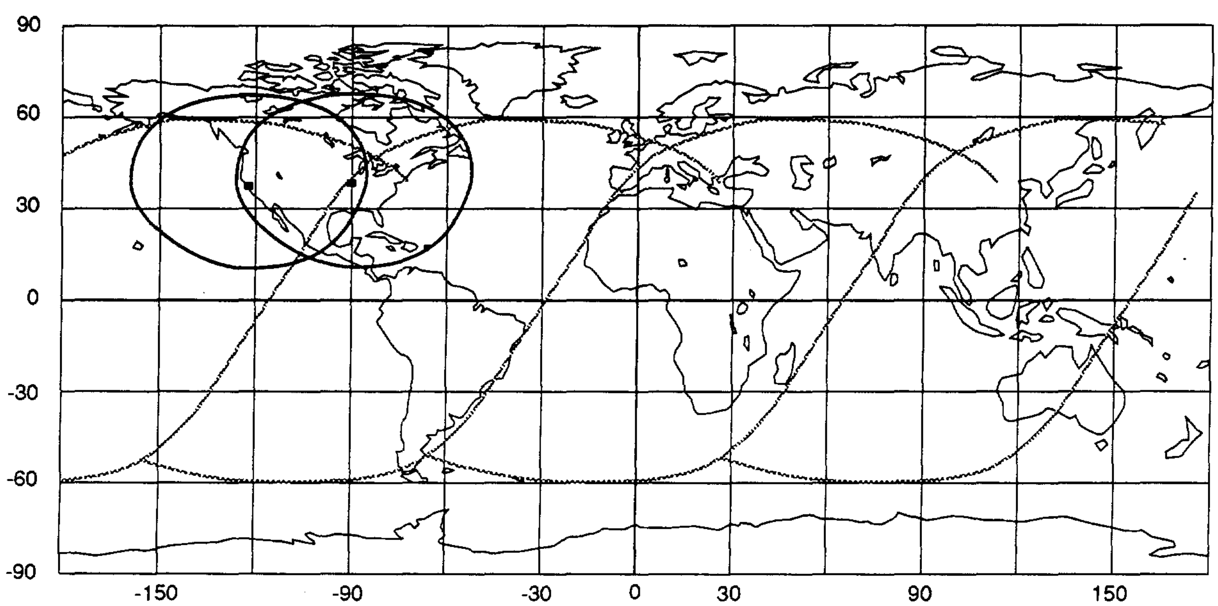
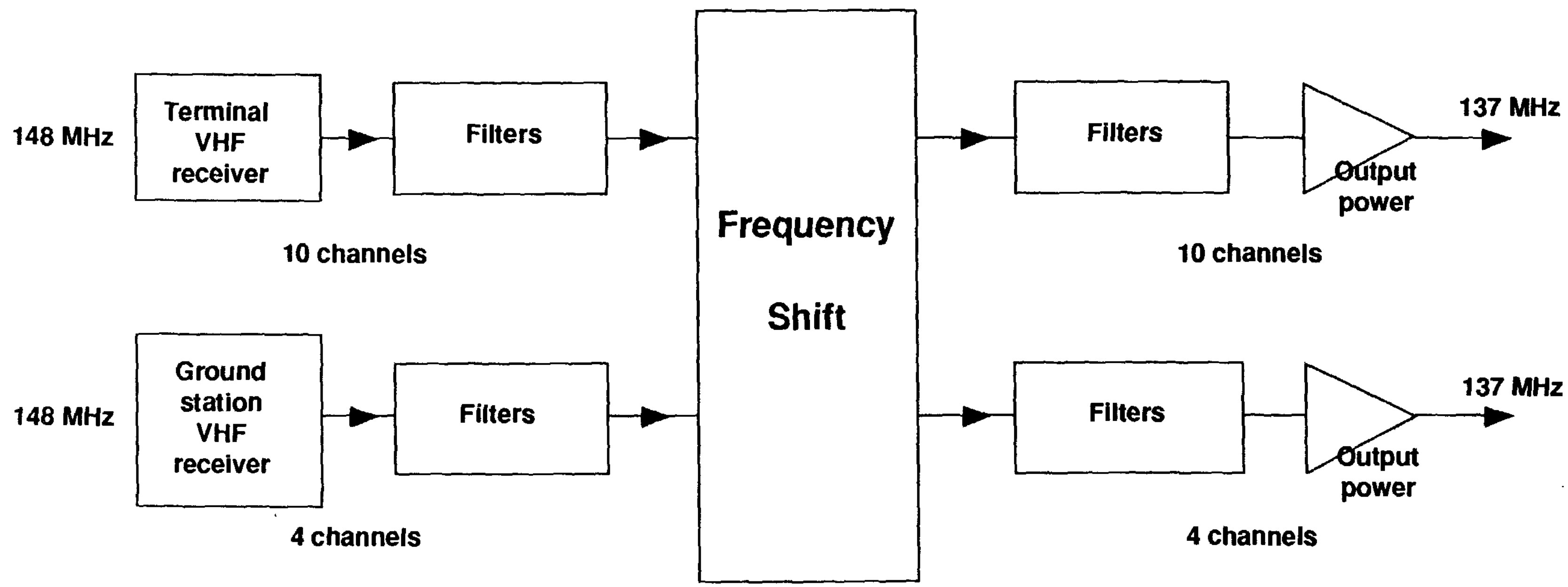


Figure VII.A.4(1)



Payload block diagram

Figure VII.A.3.2

Orbit parameters :

- Period : 1 h 51 mn 20 sec,
- Round trip signal delay : 8 msec.

Coverage performances :

The most subtle problem with the mission analysis is specifying the constellation to maximize the coverage. A key analytical tool in this study is the "central angle" C_v of the visibility cone (C_v = 29° for E_0 = 5° and altitude = 1300 km).

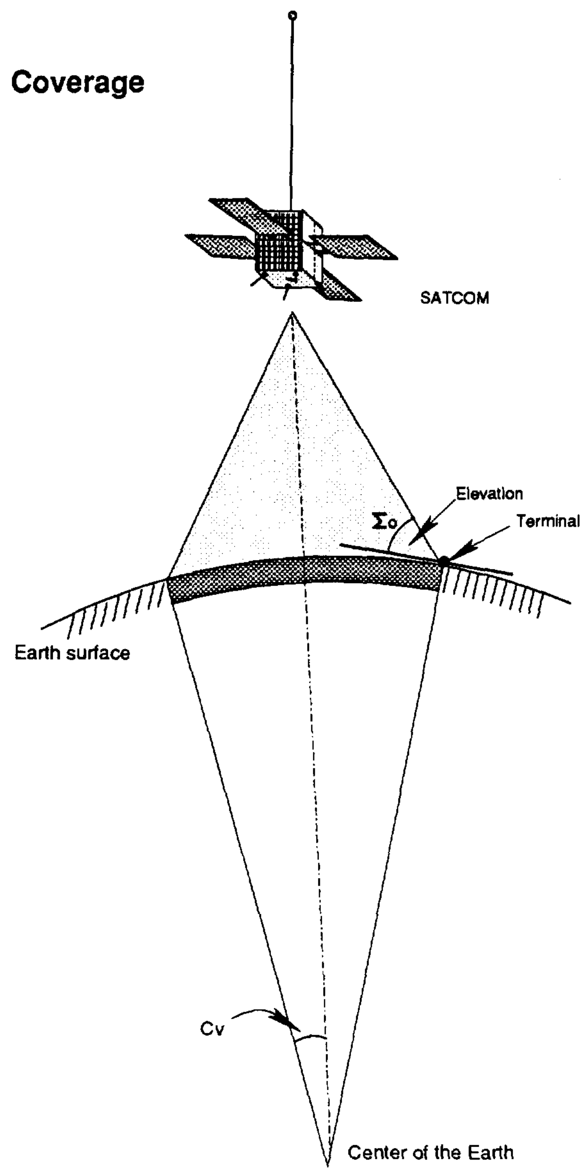


Figure VII.A.4(2)

Another important characteristic of the constellation is the maximum time that an activated terminal (anywhere on the earth) must wait to view the satellite. The mean waiting time for a terminal in the CONUS area is about 2 minutes. An example of the 24-satellite distribution coverage is given below.

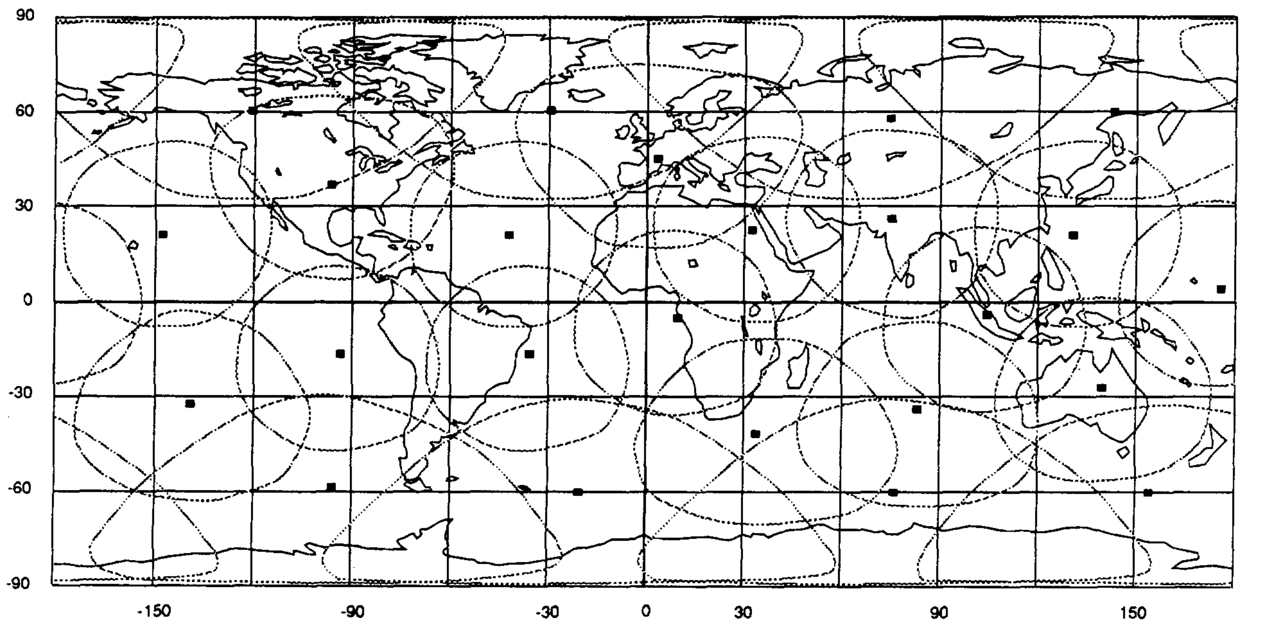


Figure VII.A.4(3)

Launch/flight sequence:

Different possibilities are presently considered for the launch of the STARNET satellite/payload :

- piggy-back on ARIANE launch (ASAP capability);
- payload piggy backing on LEO satellites (SPOT, EPOP, etc.);
- PEGASUS airplane launch technology;
- MicroSat Launch Systems (sounding rocket technology)

Orbital inclination from 50° through 60° at 1300 km (700 nmi) can be achieved using any available satellite of opportunity, i.e.: Ariane, Pegasus, etc. For a payload of about 112 kg (246 lbs) and a 1300 km circular polar orbit injection, accuracies are expected to be 37 km (20 nmi) deviation in altitude and + or - 0.2° in inclination.

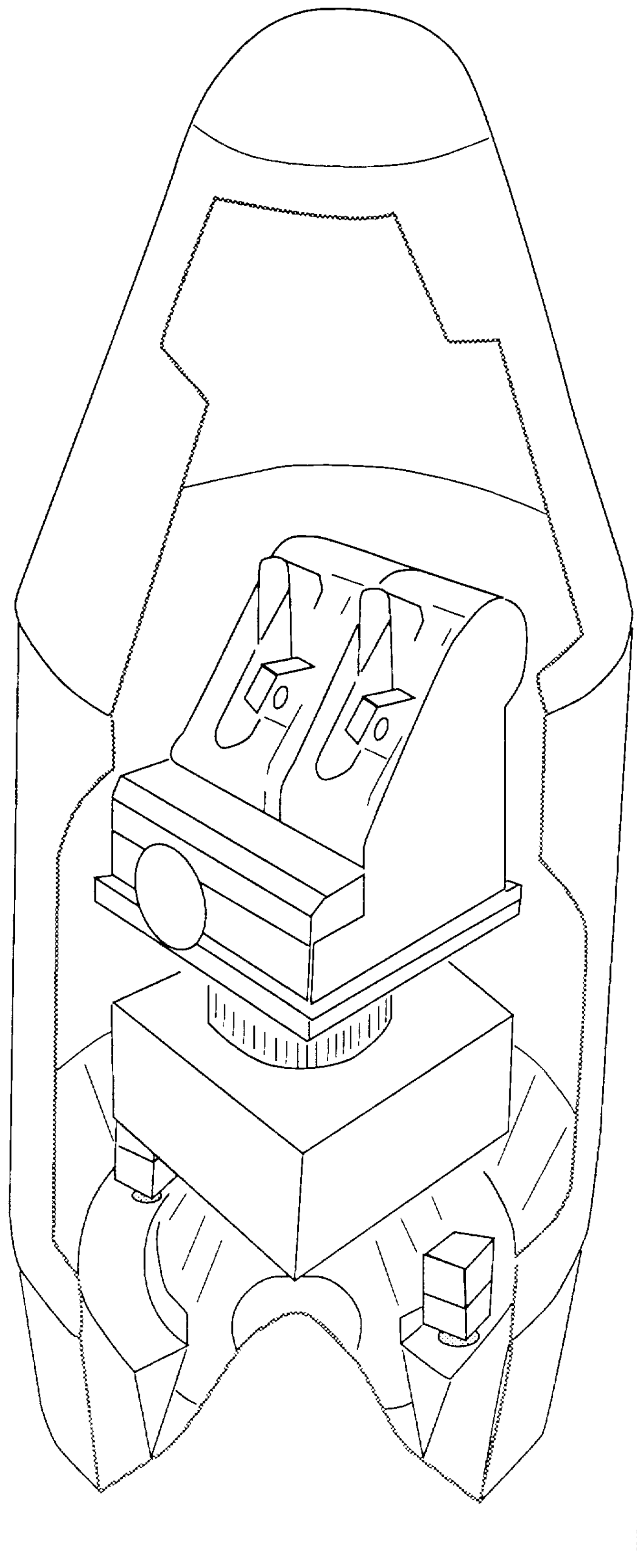


Figure VII.A.4(4)

5. Terminal Position Determination

Radio-determination will be obtained by using Ranging and Doppler measurements on received frequencies.

5.1 Principle

The Processing, Analysis and Control Centers (PACCs) will automatically assign each CDA station the task of tracking a specific spacecraft at specific times and manage conflicts in case of several spacecraft in the field of view.

When assigned to a specific spacecraft, the CDA station begins with acquisition and continues with tracking during the pass. The CDA station sends a time of reference in the OUTBOUND uplink.

When a terminal is on, it tries to synchronize on one OUTBOUND downlink. When synchronized, a light can be switched on, indicating that transmission is possible.

On a transmission request, the terminal indicates the number of the last time reference received, spacecraft ID on which it is synchronized, its own ID, type of message and data.

When this message arrives at one of the CDAs, time of arrival is measured with respect to the time reference of this CDA.

Note : Spacecraft A is synchronized by CDA station B. A user terminal is synchronized on spacecraft A. User terminal transmission can be received either by station B through spacecraft A or CDA station C, coming from spacecraft A or spacecraft D (synchronized by another CDA).

At arrival, the received frequency is also measured.

Using ranging and Doppler techniques, the user terminal position is computed when enough information is gathered.

5.2 Geometric Considerations

The first level of the positioning process is directly linked with the geometric intersection of possible positions :

- earth sphere or ellipsoid;
- sphere, the center being at the satellite's position, radius is determined by ranging;
- cone, the summit of it is also at the satellite's position, aperture is determinated by Doppler effect.

On one transmission, ranging and Doppler techniques lead to a position determination with the intersection of two spheres and one cone.

Preliminary studies show that the achieved accuracy is on the order of magnitude of 1 km, taking into account that ambiguity can be determined with supplementary information from terminal (region, ground/sea, preceding position, etc.). Positioning accuracy is directly connected with terminal performance as frequency stability.

This positioning method will be used during the first emergency phase. Then, minutes later, new information coming from the same spacecraft at a different geometric position, or another spacecraft, will allow positioning accuracy to less than 100 meters.

Influence of terminal altitude knowledge (Earth sphere radius) will be decreased using either terrain map or 3-axis computation depending on available measurements.

5.3 Filtering

When enough information is available, the same technique described above will be applied in conjunction with filtering techniques that will decrease the budget error due to noise in transmission or measurements.

5.4 Relative Positioning

Using a network of Reference Calibration Platforms (RCP's), at periodic intervals a geographical calibration of the system is performed. This allows for a compensation of systematic bias of the system due to propagation (ionospheric and tropospheric) and satellite positioning errors.

The final accuracy of STARNET positioning is better than 50 meters.

5.5 System Ultimate Accuracy

Using filtering techniques and relative positioning during several hours for a fixed terminal, final achieved accuracy will be better than 20 meters.

At this level of accuracy, one must be aware of the coordinate references used.

6. Spectrum Allocation

Applicant is requesting authorization to operate on a Modified Primary Basis in the U. S. on the following VHF bands :

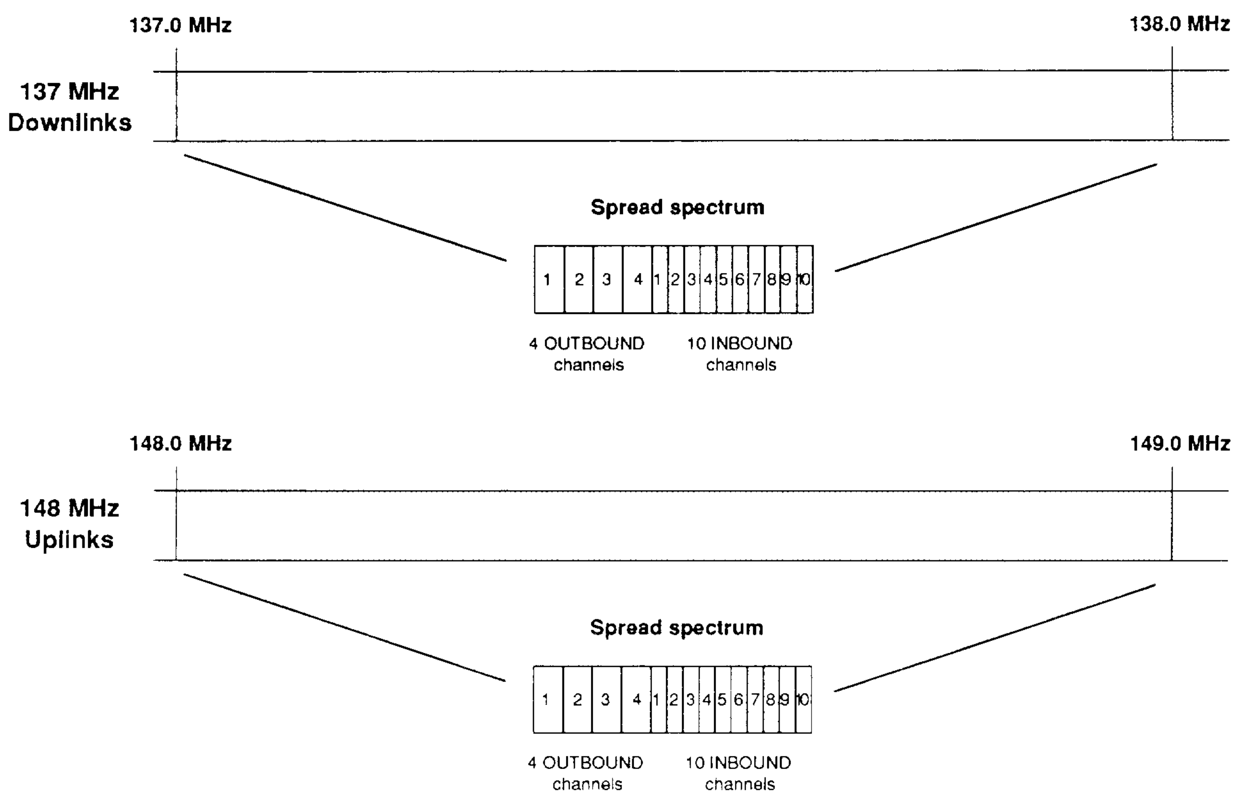
Nominally using spread spectrum techniques (Solution A)

Earth to space (uplink)	148	to	149.0 MHz
Space to earth (downlink)	137	to	138.0 MHz

Or alternatively without using spread spectrum techniques (Solution B)

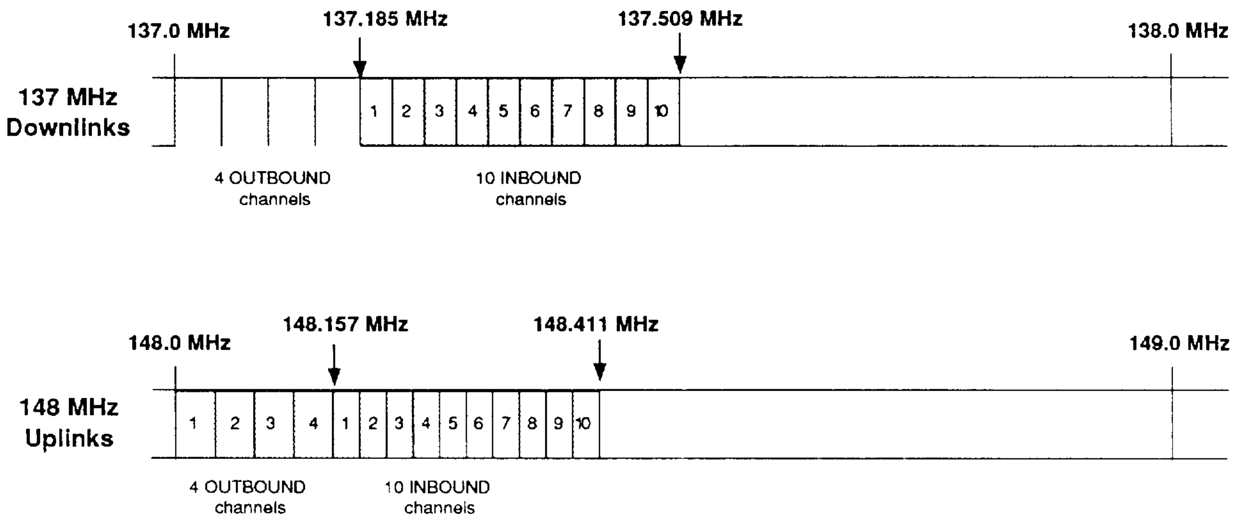
Earth to space (uplink)	148	to	148.411 MHz
Space to earth (downlink)	137	to	137.509 MHz

The "Modified Primary" basis is such that the proposed system will not cause interference to presently authorized users in the same band and would be granted Primary Status against any new services.



Base line STARNET spectrum proposal (solution A)

Figure VII.6(1)



Base line STARNET spectrum proposal (solution B)

Figure VII.6(1)

7. Interference Analysis

7.1 VHF Downlink Band (137 - 138 MHz) (spread spectrum)

This band is allocated on a Primary Basis to Space-to-Earth operations (TIROS, LANDSAT, IMP ... satellites).

7.1.1 Interference with Existing Services

The low Power Flux Density (- 141.5 dBW/m^2/ 4 kHz) of the outbound downlink referenced to a 4 kHz bandwith combined with spread spectrum should permit sharing the (137 - 138 MHz) VHF bandwith without coordination with other Space to Earth services.

7.1.2. Interference from Existing Services

STARNET user terminals are susceptible to interference from nearby fixed - mobile existing transmitters.

The potential for interference exists if transmitters are within the line of sight of the user's terminals. However, the mobile nature of the STARNET transceivers, the spread spectrum modulation used, and its acknowledgement-based protocol will minimize the operational effect of such interference.

7.2 VHF Uplink Band (148 - 149 MHz) (spread spectrum)

This band is allocated in Primary Basis to Fixed Services.

7.2.1. Interference with Existing Services

The low radiated power of the user's terminal transmitter (about 1 watt) combined with the short pulse nature of the signals and the spread spectrum modulation will help avoid interference with existing Fixed to Mobile Services.

The high directivity of the STARNET CDA station antennas will provide enough protection for existing Fixed to Mobile Services against STARNET outbound uplink.

7.2.2 Interference from Existing Services

The short pulse inbound uplink between user's terminals and the satellite, its acknowledgement-based protocol and the spectrum spreading will permit STARNET to share the inbound uplink frequency band with existing ground services.